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Radio Frequency - Intelligent Energy Conservation System through Remote Power Transferring for Wireless Sensor Devices

S. Sharmila, Dr. Antony Selvadoss Thanamani and Dr. A. Kanagaraj

***Abstract*---**Wireless Sensor networks are currently an active research area mainly due to the potential of their applications. Recent development of wireless communication and micro-electronic technologies enables the interconnection between intelligent monitoring and control devices within the home space. Sensing physical information through wireless sensors helps to automate the system and to incorporate the pervasive paradigm for various networks. Since wireless network communication provides various advantages, the main drawback is supplying power to these wireless devices. Currently there are various techniques are in use to supply power without interruption. All most everywhere using technique is battery based power supply. In this case frequently battery needs to be changed, and another method of providing power supply is attaching energy harvesting device with this wireless sensors. In this case, due to the continuous environmental change, energy harvesting may not possible at all times. All of these technologies needs more cost to deploy and more maintenance cost. To avoid this, to meet all of these requirements in this paper Radio Frequency (RF) based remote power supply is introduced.

***Keywords*---**Radio Frequency, Radio Waves, Wireless Sensor Network, Pervasive Computing, Direct Current, Energy Harvesting, Microwaves

I. INTRODUCTION

WIRELESS sensors network become a ubiquitous technology with various applications including the field of pervasive computing. Implementing wireless sensors provides better option instead of using wired network. But power supply is the challengeable factor in wireless sensor network. Normally wireless devices utilize on-board batteries with limited energy which provides only a limited lifetime. An alternative solution to this problem is wireless power supply. Nikola Telsa is the father of wireless energy transfer. Telsa, a popular electrical engineer in america, demonstrated the transmission of electrical energy without using wires to power electronic devices in 1891[15] and aspired to achieve intercontinental wireless transmission of industrial power in his unfinished Wardenclyffe Tower project [16]. Later at 1960's American electrical engineer William C. Brown designed, developed and demonstrated the microwave power transmission. In 1961 Brown published his first paper in proposing microwave energy for power transmission, and in 1964 he demonstrated [17] on Walter Cronkite's CBS Evening News a microwave-powered model helicopter that received all the power needed for flight from a microwave beam. But only recently has the concept become technologically feasible in all applications. Scientists still doing research in RF based wireless power transfer method [2, 19, 20] due to its capability of transferring power through air from one place to another place.

The main goal of implementing this technology is cutting down the cost factor of charging devices, avoid power theft and power loss that occurs during transmission and distribution. The main reason for power loss during transmission and distribution is the resistance of wires used for grid [15]. To overcome this issue, this system transfers and harvest power through air from one place to another. By implementing this technology in pervasive computing we can conserve more energy. Apart from all no physical connection is needed in complicated areas; it provides safe and efficient power transfer. Some of the external energy sources used for energy harvesting are solar, wind, temperature gradient and radio frequency [13]. Among all, radio frequency is an efficient and suitable method to transfer power. Now a day's, RF is available everywhere like mobile phone, radio, TV transmissions.

RF is a term which describes the number of times per second or oscillation of an electromagnet radiation. In frequency anything in the range between 3Hz to 300GHz is still referred to as RF waves. But still these ranges can be subdivided depending on the actual frequency. Microwave is the general term used to describe RF waves that start from 300 MHz (Ultra High Frequency) to 300GHz (Extremely High Frequency). Lower than 300 MHz is referred to as radio waves where as higher than 300GHz frequencies are called millimeter waves [19]. The figure 1 shows the ranges of Radio Frequency.

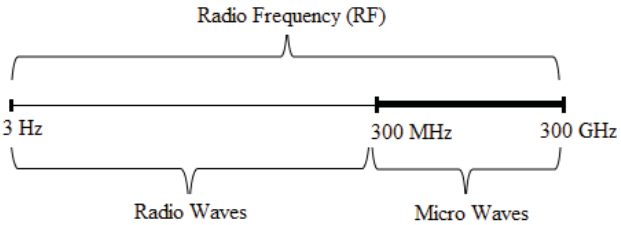

Fig 1: RF - Frequency Range

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Radio frequency can be used for various purposes but mostly it is using for the field of communications. Radio waves are normally used in radio stations. Upper spectrum of radio frequency waves (300 MHz to 300GHz) occupied by microwaves. It is being used in wider range of applications.

At present microwaves are mostly used in the field of communications. In this paper we implemented this concept to supply power for sensor devices used in pervasive computing.

II. Impact of Wireless Sensor Devices

In recent years deployment of wireless sensor network becomes popular due to its easy implementation even in places where deployment of wired network is not possible. These systems consist of spatially distributed wireless nodes. It can be used for wide range of applications [3] such as structural monitoring [4], health care systems [6, 7], environmental monitoring, habitat monitoring [5] etc. Pervasive computing is one of the emerging fields where the contribution of wireless sensor networks is more. A wireless sensor networks consists of a sink node and a number of small wireless sensor nodes. These sensor nodes collect information from environment and sent to sink node. The sink node is sometimes referred as base station. The sensory information is communicated to sink through wireless hop by hop transmissions. Then these collected data can be used locally or forwarded to central system to take prior decision to other networks like internet through a gateway.

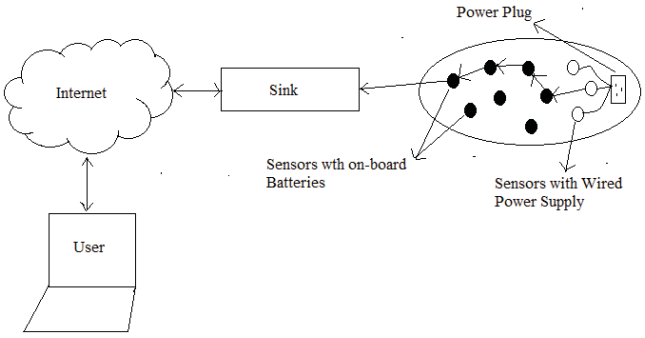

Fig 2: Wireless Sensor Network with Wired Power Supply and On-board Batteries

Energy supply for these sensors has been a key limiting factor of the life time of pervasive computing networks. Currently power has been passed to sensors either by using wired network or through on-board batteries (figure 2).

On-board batteries which have a fixed energy rating and limited lifetime. Therefore frequently the batteries have to be changed. Labor and maintenance costs can be extremely high if the networks are deployed in hard to service locations. As well as power supply through wired network also has lot of disadvantages. In wired power supply, the implementation and maintenance cost will be more. Wiring in complicated areas is not too simple such as across river or mountain or rural area. Apart from all it consumes more power. To overcome these issues, in this paper we introduced RF based [2] wireless power supply for wireless sensor devices.

III. Energy Harvesting Through Radio Frequency

Capturing energy from external sources is known as energy harvesting. Other names for this technology are energy scavenging, power harvesting etc. Wireless system is a communication of information between two points without using any solid media like wire for transformation. This can be accomplished either by using infrared, sonic, optical or radio frequency [18]. At early days TV remote controllers used ultrasonic signals, but the drawback in this system is, it provides very low data rates and poor immunity of interference. Infrared signals can provide moderate data rates compared to sonic. But only it can able to communicate with in shot range, because infrared radiation signals easily blocked by any obstacles. Optical signals propagate in an unobstructed environment can provide moderate to high data rates, but it requires line-of-sight path. Also it cannot be used where dust, fog, or foliage can block the signal. But while using RF we can able to pass signals for long range efficiently. None of the obstacles can block the signals including vehicles, buildings etc. In this paper we have chosen RF signal to transfer power to low power sensor devices.

We can categorize the wireless system based on the mode of transmitter and receiver antennas used. In a point-to-point radio system, single transmitter and single receiver used. In this system single transmitter communicates with single receiver. Next type is single-point to multi-point radio transmission system. In this system single transmitter sends signal to large number of receivers. An example for this system is FM broadcasting radio. In Multi-point to Multi-point system simultaneously more than one transmitter communicates between more than one receiver [18]. In this paper we are implementing single point to multipoint communication system for transfer energy to wireless sensors devices used in pervasive computing.

This system eliminates the physical power connection between power source and sensor nodes. The power is transferred through air from one place to another. The major advantage of using this system is, it transfers power to wireless sensor devices located in difficult access environments [17]. Apart from all the direction of energy transformation can be rapidly changed, microwave energy can be transferred at the velocity of light, it eliminates mass, and it losses only small amount of energy compared to wired power supply. The basic principle of this kind of power transformation is presented in figure 3.

The process of radio power transmission can be divided into three steps. At first step Dc power is converted into RF power. Then converted RF power is transferred through air using antenna. Finally wirelessly transmitted RF energy can be received using antenna and converted back to DC power and stored it in a super capacitor to provide required energy to sensors in WSN.

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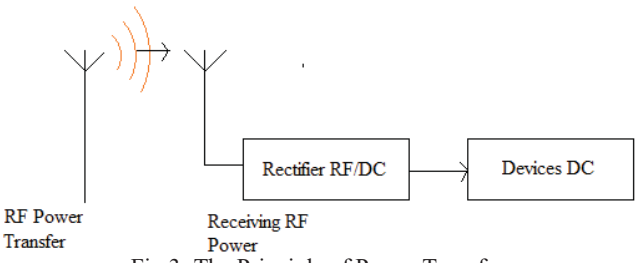

Fig 3: The Principle of Power Transfer

The efficiency of power transmission is fully associated with the combination of all these process. Recently there has been a lot of research is going on in development of components to get high efficiency, high reliability, low mass and low cost.

IV. Wireless Sensors Powered by RF Technology

A major technical challenge in deploying wireless sensor network in pervasive computing is the way of power supply. In this paper we have introduced new concept of wirelessly supply power using radio frequency. Radio frequency is a common word which describes a rate of oscillation in the range of 3 Hz to 300 GHz, which corresponds to the frequency of radio waves and the alternative currents which carry radio signals. Radio Frequency communication woks by creating electromagnetic waves at a source and being able to pick up those signals at destination point. The speed of transferring signals is almost near to the speed of light. These electromagnetic waves pass through the air from one point to another. RF field has both electric and magnetic component. Radio Frequency waves can be characterized by a wavelength and frequency.

The wavelength is the distance covered by one complete cycle of the electromagnetic wave, while the frequency is the number of electromagnetic waves passing a given point in one second. The wavelength of the frequency is inversely proportional to the frequency, the lower the frequency, the longer the wavelength. The frequency of RF signal is measured in units of Hz. Different forms of electromagnetic energy are categorized by their wavelengths and frequencies. In general longer wavelengths travel a longer distance and passes through the objects compare to shorter wavelengths. The Federal Communications Commission (FCC) and other regulatory bodies around the world have set up a serious of regulations defining the emission levels and usage for different frequencies.

The conversion of microwave signals to DC power has been proposed and researched in the context of high-power beaming since the 1950s [9]. It has been proposed for solar power satellite (SPS) [10], helicopter powering [11], the SHARP System [12], and recently for RFID system. In this paper we focus on RF energy. We propose to use the energy from commercial RF broadcasting stations like GSM, TV, WIFI or Radar to supply energy for wireless sensor nodes used in pervasive computing. This powering method can be especially interesting for sensor nodes located in remote places, where other energy sources like solar or wind energies are not feasible. Two antennas were used for power supply; one is for transferring power from power source to destination point and another one is used to receive RF energy and supply it to sensor devices.

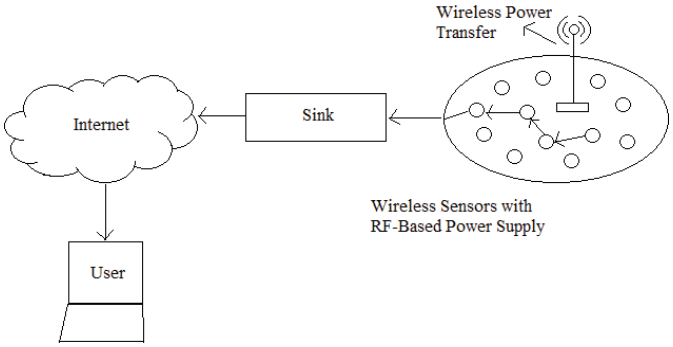

Fig 4: Wireless Sensor Network with RF based Wireless Power Supply

V. Power Conservation By Using Radio Frequency Based Wireless Power Supply For Pervasive Wireless Sensor Devices

Wireless sensors monitoring system is a promising solution for decreasing the installation and maintenance cost compare to wire based monitoring system. Even though wireless sensor network technologies have many advantages for various applications, still challenges exist when they are applied for pervasive computing. Wireless pervasive computing is a rapidly developing area. The main limitation is supplying power. Sensor networks utilize either wired grid power supply or on-board batteries with limited energy that cannot be replenished in most application scenarios [1]. Wireless sensors need to operate long time, but batteries used in sensors have only fixed amount of energy. Therefore, in order to provide continuous power supply and to avoid power consumption of various components (such as network interface cards, switches, routers, cables etc.,) that constitute the pervasive infrastructure we need to go for novel wireless powering method. Wireless powering is an alternative solution for continuous power supply. Various wireless powering methods have been proposed in the past. Among all the most common form of wireless power transmission is carried out using RF. It can able to transfer long range compare to near-field inductive coupling or strong resonant coupling. Normally this kind of power transformation method useful in the places where sensors located in inaccessible areas which fitted with large size batteries.

Battery-based devices are easy to deploy but the batteries, inexpensive themselves, eventually fail and the on-going maintenance cost to replace them is very expensive. In addition, premature battery failure or lack of discipline in replacing them can cause users to miss out on intended benefits such as optimized system performance and lack of receiving information to take prior decision to avoid more power consumption. The pervasive computing needs low-cost, reliable, and long-term power sources to scale wireless sensor networks and extend deployment into hard-to-service areas

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where wiring or replacing batteries is impractical or prohibitively expensive.

As a result, there is tremendous interest in energy sources that can power sensors autonomously for the life of the application without wires or primary batteries. This is commonly referred to as micro-power energy harvesting where microwave energy from radio frequency is converted into electrical energy. While RF has been popular for years, other types of energy-harvesting technologies have emerged for micro-power applications including vibration, thermal, wind and mechanical. While the power from RF energy is typically very low, RF energy is unique among energy-harvesting options because it can either be harvested from ambient energy or intentionally broadcasted to provide more reliable power-over-distance using very little energy from the electric grid. Embedding wireless power technology in sealed devices that are protected from moisture and other environmental conditions improves reliability, extends lifecycles and frees systems from connectors, cables, and user access.

Rechargeable batteries normally stored for long periods can also be trickle-charged and maintained at the preferred voltage for safety or battery cell performance. At longer range, RF energy can power battery-based or battery-free remote sensors for environmental monitoring and building automation. Depending on the power requirements and system operation, power can be broadcasted continuously, on a scheduled basis, or on-demand. RF based power supply is best used for devices with low power consumption and long or frequent charge cycles. Typically, devices that operate for weeks, months, or years on one set of batteries are essentially required wireless recharging using RF energy. A network of transmitters can be positioned in a facility to provide wireless power on a room-by-room basis, or to create a many-to-many charging topology.

Sensor networks represent basic elements of emerging pervasive environments. Sensor nodes are small devices with computing, communication and sensing capabilities that can be used for various purposes. Typical sensing tasks could be light, Pressure, vibration, temperature, sound etc. Different kinds of "infrastructures" can be deployed to deliver the collected information from the sensing field to the place this information is elaborated. In recent years, advances in simple, low power, and efficient wireless communication equipments made wireless sensor networks the most interesting way to deliver the sensed data to the mobile device(s) in charge to collect/elaborate them. However, due to the technologic constraints, single-hop wireless communications are not efficient from the power consumption standpoint, and multi-hop communications are typically used to deliver the collected information. Specifically, a wireless sensor network is typically organized as shown in Figure 5.

This diagram clearly depicts, there were two transmitters used to create a wireless micro-power grid as well as unlimited receivers used within range of a power transmitter. Transmitter's transfers microwave energy through air to the sensors. In opposite side the receiver antennas receives the microwave energy and convert it to DC power and supply it to the sensor devices which is used in pervasive computing.

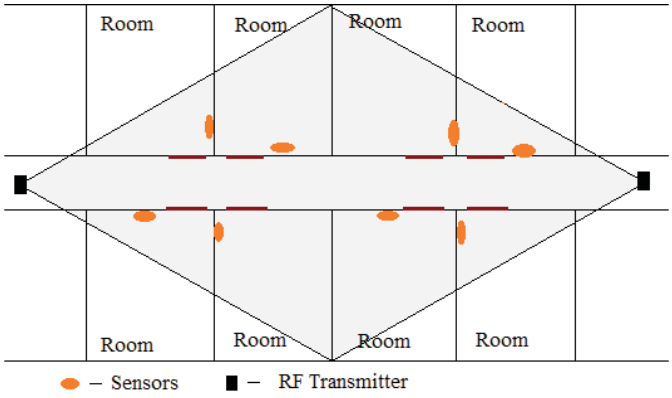

Fig 5: Wireless Power Transfer (RF)

The sensor devices are closely and randomly deployed inside the area in which a phenomenon is being monitored. Each sensor devices delivers the collected data to one or more neighbor device, one hop away. By following a multi-hop communication paradigm the data are routed to the sink and through this to the user (see figure 4). Therefore, multi-hop ad hoc techniques constitute the basis also for wireless sensor networks.

Efficiency of RF is comparable to traditional power sources; it transfers power at rates up to 98 percent and reduces energy being wasted through inefficient chargers. It supplies only the necessary power needed to fuel electronics. If we use power card to transfer current, resistance will consume some amount of power. This amount of power can also be conserved by using this technology. This consumed power can be calculated by using formula;

$$\text{Volts} = \text{amps} * \text{ohms}$$

$$\text{Power} = \text{volts}^2 / \text{resistance}$$

So after peer review, we found power loss is the major issue during transmission. As the demand increases day by day, the power generation increased as well as power loss is also increased. Approximately 26% of power losing during transmission. The reason for power loss during transmission and distribution is the resistance of wires used in grid. According to the world Resources Institute (WRI), India's electricity grid has the highest transmission and distribution losses in the world - Approximately 27% to 40% [5]. This happening due to grid inefficiencies and power theft. Also we have discussed battery based power supply also not a suitable method for power supply. So to solve these problems in this paper we have introduced RF based wireless power transmission method. By implementing this new method for wireless sensors which is used in pervasive computing we can conserve more power by avoiding loss of power.

VI. CONCLUSIONS

This paper introduced new method of remote power supply for wireless sensor devices. It avoids various complexities faced by wired power supply, battery based power supply and

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power supply through energy harvesting device attached with it. All these methods are replaced with RF based power supply, which avoids installation and maintenance cost. This also reduces the transmission and distribution data loss. This new approach can efficiently capture the microwave energy by using different kinds of antennas and converted it to DC power and transfer to sensor devices. This new system conserves more energy by regulates the RF based power supply to sensor devices. In future we are planning to found solution for wirelessly transfer power to all electronic devices used in pervasive computing.

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